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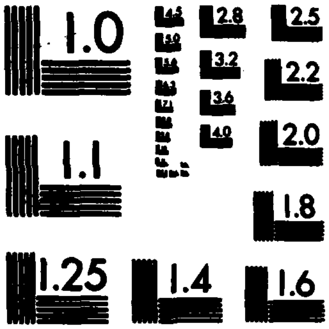

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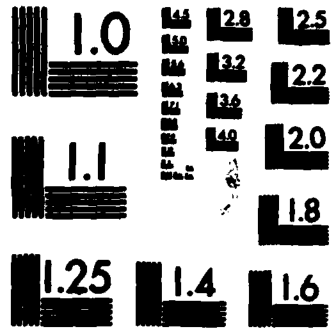

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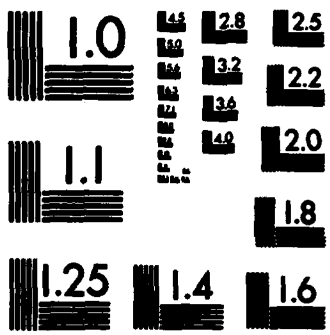

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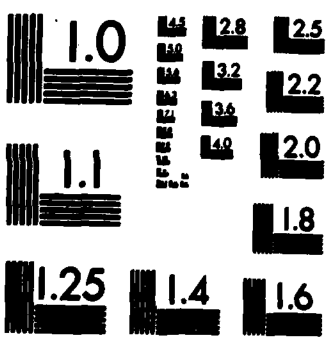

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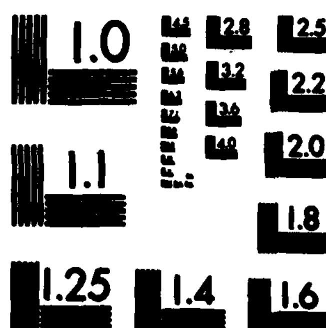

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CALCULATION OF THE DOSE RATE EMANATING FROM GAMMA RADIATION OF A GAS JET PROPAGATING THROUGH THE SURFACE LAYER OF THE ATMOSPHERE

by

O.V. Zakharov, V.V. Kovalenko, and V.M. Kolobashkin

FOREIGN TECHNOLOGY DIVISION

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By: O.V. Zakharov, V.V. Kovalenko, and V.M. Kolobashkin

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О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	sinh^{-1}
cos	cos	ch	cosh	arc ch	cosh^{-1}
tg	tan	th	tanh	arc th	tanh^{-1}
ctg	cot	cth	coth	arc cth	coth^{-1}
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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CALCULATION OF THE DOSE RATE EMANATING FROM GAMMA RADIATION OF A GAS JET PROPAGATING THROUGH THE SURFACE LAYER OF THE ATMOSPHERE

O. V. Zakharov, V. V. Kovalenko, and
V. M. Kolobashkin.

Using the principle of the semiempirical theory of turbulent diffusion, work [1] has solved the problem of a radioactive mixture propagating in the surface layer of the atmosphere.

Let us examine the problem of calculating the dose rate on the earth's surface which emanates from a gas jet, whose concentration of activity is distributed in accordance with the solution derived in work [1], for the various energies of the gamma quanta and varied meteorological conditions.

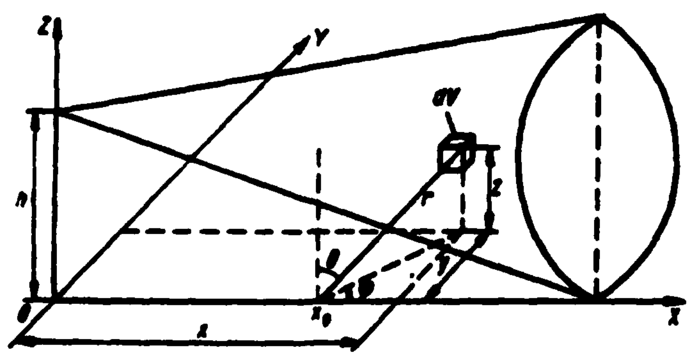

Fig. 1. Geometry for calculating the dose rate.

Dose rate $P(x_0)$ at point x_0 (Fig. 1) from a volume source can be calculated by the formula

$$P(x_0) = \sum_i K_{\gamma_i} \iiint_V q(x, y, z) \frac{e^{-\mu_i r}}{r^2} B_D(\mu_i r)\, dV \left[\frac{р}{ч}\right], \qquad (1)$$

where $q(x, y, z)$ is the activity concentration obtained in work [1], curie/m^3; K_{γ_i} - differential gamma constant of an isotope, $p \cdot m^2/(h \cdot$ curie); r - distance from the volume element dV (m^3) to the point x_0, m; μ_i - linear coefficient of attenuation of gamma radiation with the energy E_i, m^{-1}; $B_D(\mu_i r)$ - dose accumulation factor proposed in work [2] for $E_i \geq 0.5$ MeV and in work [3] for $E_i < 0.5$ MeV; the sum is taken over all the gamma lines of a given isotope.

Integration is performed with respect to the entire jet volume V, where the activity concentration is different from zero. Fig. 1 shows the relationship between the rectangular and spherical coordinates.

If points x_0, in the dose rates are being calculated, lie at the projection of the jet's axis on the earth's surface, then, due to the symmetry of the problem relative to the XOZ plane, the ϕ integral is selected in the range from 0 to π and it is doubled.

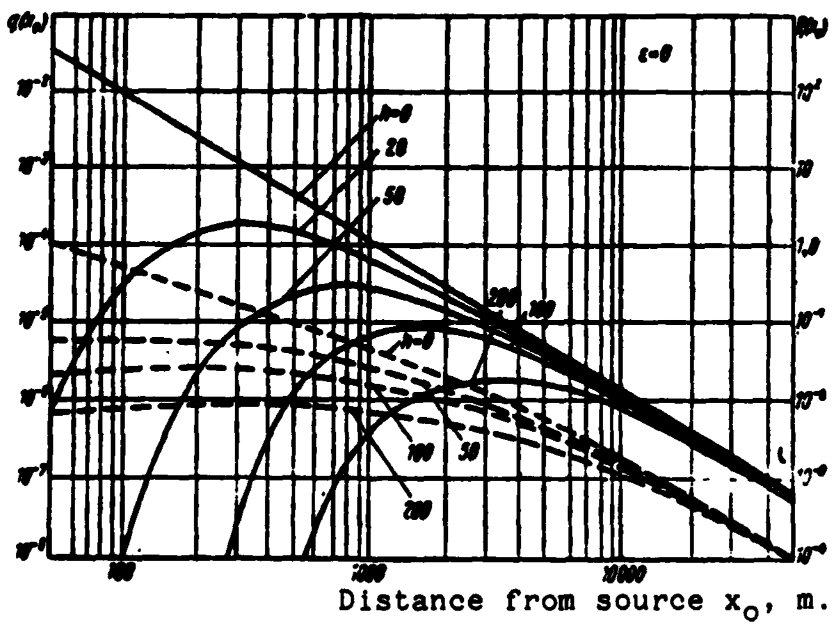

Fig. 2. Cited surface concentrations $q(x_0)$ (———) and dose rate $P_1(x_0)$ (– – –) as functions of the distance to source x_0.

The function $P_1(x_0, E_i)$, which numerically equal to the dose rate in p/h created by the gamma radiation of the jet flowing from a source with power Q_0=1 curie/s with the wind velocity v=1 m/s, was calculated for a long-lived isotope with $K_r = \frac{p \cdot m^2}{h \cdot curie}$. Thus, below we will refer to the function $P_1(x_0, E_i)$ as the reduced dose rate.

The upper limit of integration with respect to r – R=800 m (using the computer, we have determined that the contribution when integrating for R≥800 m yields an addition of less than 1% of P_1 when R=800 m). The absence of the jet at points x≤0 was taken into account by the fact that the integrand was assumed to be zero for points x_0<800 m, for $x = x_0 + r \sin\theta \cos\phi \leq 0$.

Integral (1) was calculated by a numerical method using the Simpson's formula. In our case, the initial subdivision steps are

$$\Delta\varphi_{\text{нач}} = \frac{\pi}{12},\ \Delta\theta_{\text{нач}} = \frac{\pi}{16} \text{ and } \Delta r_{\text{нач}} = 20 \text{ m}.$$

After calculating with the initial step, this step is reduced one-half and the integral is calculated again, etc. The calculations using each variable end when the next decrease of the subdivision step by one-half yields the relative correction of the integral value of less than 10^{-2}. The reduced dose rate was calculated on a digital computer for the energies of the gamma quanta E_i (MeV)=0.10–2.5 and six values of the atmosphere-stability parameter ε=–0.3; –0.2; –0.1; 0.0; 0.1; and 0.2.

The reduced dose rates calculated thus for the most frequently encountered indifferent stratification of the atmosphere (ε=0) are represented in Fig. 2 by dashed curves as functions of distance to the source for gamma radiation with E_i=1 MeV. In the same figure, the solid lines depict the reduced surface concentration $q(x_0)$ as a function of distance to the source, which is numerically equal to the concentration of the long-lived gaseous isotope in curie/m^3 from a source with power Q_0=1 curie/s at the wind velocity v=1 m/s at the points lying at the projection of the jet's axis on the earth's surface. The reduced surface concentration has the dimensionality [m^{-2}].

The values of the reduced dose rate are shown on the right axis of the ordinates, the values of the reduced surface concentration - on the left axis of the ordinates.

The reduced dose rate P_1 has a slight dependence on the energy of

gamma radiation: in the energy range from 0.1 to 2.5 MeV it changes by $\pm 30\%$ from the values with $E_i = 1$ MeV. The dependence of P_1 on the distance to the source is the same for all energies of the range examined.

The following formula can be used to calculate the dose rate P from a source with power Q (curie/s) for a specific isotope with the wind velocity v (m/s):

$$P(x_0) = \frac{Q}{v} \sum_i K_{\gamma_i} P_1(x_0, E_i) \cdot \frac{\rho}{4}. \qquad (2)$$

Taking into account the slight dependence of $P_1(x_0, E_i)$ on energy E_i with an error $\leq 30\%$, the expression for the dose rate from the gamma radiation of a specific isotope can be written as

$$P(x_0) = \frac{Q}{v} K_\gamma P_1(x_0) \cdot \frac{\rho}{4}, \qquad (3)$$

where K_γ is the complete gamma constant of the isotope, $\frac{p \cdot m^2}{h \cdot curie}$.

The effect of the radioactive decay of the isotope with $\lambda \neq 0$ can be taken into account by multiplying the value of $P(x_0)$, calculated by formula (2) or (3), by $e^{-\lambda \frac{x_0}{v}}$. Calculation on the computer shows that in taking into account the decay of the isotope

$$P(x_0, \lambda) = P(x_0) e^{-\lambda \frac{x_0}{v}}, \qquad (4)$$

where $P(x_0, \lambda)$ is the dose rate at distance x_0 from the source for an isotope with the decay constant λ; $P(x_0)$ - analogous dose rate from a long-lived isotope - yields diffference from the values of $P(x_0, \lambda)$ calculated by formula (1) with the addition of the term, which takes into account a decay of not over 8% for the isotopes with a half-decay period $T_{1/2} \geq 20$ min and $x_0 \geq 1 \cdot 10^3$ m with the wind velocity $v = 1$ m/s. This difference is less for high wind velocities.

It can be seen from Fig. 2 that the position of the maximum of surface concentration of the isotope does not coincide with the position of the maximum of the surface dose rate from the gamma radiation of the same isotope. This noncoincidence of the maxima is observed at all the energies of the gamma quanta and meteorological parameters observed. The maximum of the surface dose rate, in the case of a raised source ($h \neq 0$), is not clearly expressed and is located at short distances from

the source. We have the same thing for the stable ($\varepsilon>0$) and unstable ($\varepsilon<0$) temperature stratifications of the atmosphere.

In all these cases, the maxima of surface concentration of gases are located considerably further from the source.

These relationships between the maxima of surface dose rate and surface concentration of gases must be taken into account when determining the dimensions of the safety zones for the concerns in atomic industry.

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